Series of Crop Specific Biology Documents

Biology of *Abelmoschus esculentus L.* (Okra)

सत्यमेव जयते

Ministry of Environment and Forests
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Consultation process:

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FOREWORD

India is one of the leading countries having an active agricultural biotechnology research and development programmes in diverse crops including cereals, vegetables, oilseeds etc. and traits such as insect, disease, and virus resistance, herbicide tolerance, stress tolerance etc. The successful development and commercialization of biotech derived crops also referred as genetically engineered (GE) or genetically modified (GM) crops requires a science based regulatory process to address the concerns arising out of genetic manipulation to human health and environment.

The Department of Biotechnology (DBT), as one of the implementing agencies for biosafety regulations in India has been providing science based support for evaluating the GM crops by preparing various guidance documents and disseminating information through websites. In continuation with the above efforts, a need was felt to prepare crop specific biology documents to provide relevant baseline information about various crops in a readily accessible format.

I am pleased to note that Dr. K.K. Tripathi, Advisor, DBT and Member Secretary, RCGM has put in considerable efforts in putting together a series of five crops specific biology documents on cotton, brinjal, okra, maize and rice, in association with the Ministry of Environment and Forests (MoEF). The biology documents have been put through a consultative process with various stakeholder viz. agriculture research institutions, state agricultural universities, industry etc. The views have been taken by circulating the documents to relevant institutions as well as by placing them on websites. The documents have also been reviewed by the members of RCGM and GEAC. Biotech Consortium India Limited (BCIL) provided support in compiling the baseline information, as well as the consultative process.

I believe that these crop specific biology documents would be of immense value for both the developers in planning the safety assessment of their products as also the regulators for evaluating the data submitted to them. Scientific developments being advancing at a rapid rate, I hope that these biology documents would be continuously updated from time to time.

(M.K. Bhan)

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PREFACE

Genetically engineered (GE) crops are regulated products in view of various concerns for human and animal health and environment. Extensive evaluation and regulatory approval process take place before any GE crop is introduced for cultivation. The approval for release of a GE crop is given by the Genetic Engineering Approval Committee (GEAC) functioning in the Ministry of Environment and Forests (MoEF) as per "Rules for the manufacture, use, import, export & storage of hazardous microorganisms, genetically engineered organisms or cells, 1989" notified under the Environment (Protection) Act, 1986.

So far, Bt cotton, is the only GE crop approved for commercial cultivation in India. There are several crops under various stages of research, development and field trials. The present set of crop specific biology documents has been prepared jointly by MoEF and the Department of Biotechnology (DBT) to provide scientific baseline information used for safety assessment of GE crops. These biology documents have sections on taxonomy, economic importance, centre of origin, growth and development (vegetative and reproduction biology), ecological interactions, distribution pattern in India etc.

I wish to put on record my appreciation of the sincere efforts put in by Dr. Ranjini Warrier, Director, MoEF who has worked closely with DBT and other stakeholders for this initiative and the consultative approach adopted in finalizing these documents. I also acknowledge the support of members of both GEAC and RCGM for their useful inputs during the review process. The inputs and support provided by Dr O.P. Govila, Former Professor of Genetics, Indian Agricultural Research Institute (IARI) and Dr. Vibha Ahuja, General Manager, Biotech Consortium India Limited (BCIL) has also been extremely valuable.

I am sure that these crop specific biology documents would serve as practical tools for researchers, regulators and industry.

(M.F. Farooqui)

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PROLOGUE

Modern biotechnology like any new technology has its associated benefits and risks. Accordingly products of modern biotechnology like biopharma, genetically engineered (GE) crops etc. are regulated for ensuring safety to human and animal health and environment. In case of GE crops, scientific assessments ensure food safety and environmental safety, an integral part of approval process. The whole process of safety assessment is based upon comparison between genetically engineered crop and its unmodified counterpart and thus requires a broad understanding and knowledge of various features of the crop plants. This familiarity with the crops allows both the developers and regulators to draw on previous knowledge and experience to ensure safety of the GE crops.

Keeping in view the above, the Department of Biotechnology (DBT) and the Ministry of Environment and Forests initiated the preparation of a "Series of Crop Specific Biology Documents" to provide information directly relevant to safety assessment in a readily accessible format. The objective of these documents is to make available the information about biology of the crops to applicants as information in applications to regulatory authorities; to regulators as a guide and reference source in their regulatory reviews; and for information sharing, research reference and public information. To start with, crop specific documents for five crops viz. cotton, brinjal, maize, okra and rice have been prepared. In addition to the scientific literature and references, the documents have also taken into account the information available in Consensus documents published by OECD as well as biology documents by other countries. The documents have been finalized through a consultative process with the concerned research institutions, state agricultural universities and subject experts. The documents were also placed on DBT's biosafety website for public review.

It is proposed to continue this exercise for more crops such as mustard, potato, tomato etc. that are under development. The support from various technology developers from both public and private sector, state agricultural universities, agricultural research institutions and other subject experts in providing information as well as reviewing these documents is acknowledged. We also appreciate the assistance provided by Dr. Vibha Ahuja, General Manager, Biotech Consortium India Limited, Dr. O.P. Govila, Former Professor of Genetics, Indian Agricultural Research Institute and other team members at BCIL for backend support in finalizing these documents.

Dr. Ranjini Warrier **Dr. K.K. Tripathi**

CONTENTS

BIOLOGY OF *ABELMOSCHUS ESCULENTUS* L. (OKRA)

1. GENERAL DESCRIPTION

Okra *Abelmoschus esculentus* L. (Moench), is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. This crop is suitable for cultivation as a garden crop as well as on large commercial farms. It is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malayasia, Brazil, Ghana, Ethiopia, Cyprus and the Southern United States. India ranks first in the world with 3.5 million tonnes (70% of the total world production) of okra produced from over 0.35 million hectare land (FAOSTAT, 2008).

Okra is known by many local names in different parts of the world. It is called lady's finger in England, gumbo in the United States of America, guino-gombo in Spanish, guibeiro in Portuguese and bhindi in India. It is quite popular in India because of easy cultivation, dependable yield and adaptability to varying moisture conditions. Even within India, different names have been given in different regional languages (Chauhan, 1972).

Okra is cultivated for its green non-fibrous fruits or pods containing round seeds. The fruits are harvested when immature and eaten as a vegetable. Okra fruit can be cooked in a variety of ways (Box 1).

Box 1: Uses of Okra in Various Countries

In Iran, Egypt, Lebanon, Israel, Jordan, Iraq, Greece, Turkey and other parts of the eastern Mediterranean, okra is widely used in a thick stew made with vegetables and meat. In Indian cooking, it is sauteed or added to gravy-based preparations and is very popular in South India. It became a popular vegetable in Japanese cuisine towards the end of the 20th century, served with soy sauce and katsuobushi or as tempura. It is used as a thickening agent in Charleston gumbo. Breaded, deep fried okra is served in the southern United States. The immature pods may also be pickled. Okra leaves may be cooked in a similar manner as the greens of beets or dandelions. The leaves are also eaten raw in salads.

The roots and stems of okra are used for clarification of sugarcane juice from which gur or brown sugar is prepared (Chauhan, 1972). Its ripe seeds are roasted, ground and used as a substitute for coffee in some countries. Mature fruits and stems containing crude fibre are used in the paper industry. Extracts from the seeds of the okra is an alternative source for edible oil. The greenish yellow edible oil has a pleasant taste and odour, and is high in unsaturated fats such as oleic acid and linoleic acid. The oil content of the seed is quite high at about 40%.

Okra provides an important source of vitamins, calcium, potassium and other mineral matters which are often lacking in the diet in developing countries (IBPGR, 1990). The composition of edible portion of okra is given in Table 1.

Table 1: Composition per 100 g of edible portion of okra

Calories	35.0	Calcium (mg)	66.0
Moisture (g)	89.6	Iron (mg)	0.35
Carbohydrates (g)	6.4	Potassium (mg)	103.0
Protein (g)	1.9	Magnesium (mg)	53.0
Fat (g)	0.2	Copper (mg)	0.19
Fibre (g)	1.2	Riboflavin (mg)	0.01
Minerals (g)	0.7	Thiamine (mg)	0.07
Phosphorus (mg)	56.0	Nictonic acid (mg)	0.06
Sodium (mg)	6.9	Vitamin C (mg)	13.10
Sulphur (mg)	30.0	Oxalic acid (mg)	8.0

Source: *Gopalan et al., 2007*

Okra is said to be very useful against genito-urinary disorders, spermatorrhoea and chronic dysentery (Nadkarni, 1927). Its medicinal value has also been reported in curing ulcers and relief from hemorrhoids (Adams, 1975).

2. TAXONOMY, GEOGRAPHIC ORIGIN AND DISTRIBUTION

2.1 Taxonomy

Okra was earlier included in the genus *Hibiscus,* section *Abelmoschus* in the family Malvaceae (Linnaeus, 1753). The section *Abelmoschus* was subsequently proposed to be raised to the rank of distinct genus by Medikus, 1787. The wider use of *Abelmoschus* was subsequently accepted in the taxonomic and contemporary literature (Hochreutiner, 1924).

This genus is distinguished from the genus *Hibiscus* by the characteristics of the calyx, spathulate, with five short teeth, connate to the corolla and caducous after flowering (Kundu and Biswas, 1973; Terrell and Winters, 1974).

Name	Okra
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Malvales
Family	Malvaceae
Genus	*Abelmoschus*
Species	*esculentus*

About 50 species have been described by taxonomists in the genus *Abelmoschus.* The taxonomical revision undertaken by van Borssum Waalkes (1966) and its continuation by Bates (1968) constitutes the most fully documented studies of the genus *Abelmoschus*. Taking classification of van Borssum Waalkes as the starting point, an up-to-date classification was adopted at the International Okra Workshop held at National Bureau of Plant Genetic Resources (NBPGR) in 1990 (IBPGR 1991) as given in Table 2.

Table 2: Classification in the genus *Abelmoschus* adopted by IBPGR, 1991

S.No.	Species
1.	*A. moschatus* Medikus- subsp. *moschatus* var. *moschatus*- subsp. moschatus var. *betulifolius* (Mast) Hochr- subsp. *biakensis* (Hochr.) Borss. subsp. *tuberosus* (Span) Borss.
2.	*A. manihot* (L.) Medikus- subsp. *tetraphyllus* (Roxb. ex Hornem.) Borss. var. *tetraphyllus* - var. *pungens*
3.	*A. esculentus* (L.) Moench
4.	*A. tuberculatus* Pal & Singh
5.	*A. ficulneus* (L.) W & A.ex. Wight
6.	*A. crinitus* Wall.
7.	*A. angulosus* Wall. ex. W, & A.
8.	*A. caillei* (A. Chev.) Stevels

Out of the above, the first three species are wild and cultivated forms, whereas the remaining are all wild forms.

The adoption of this new classification requires the amendment of the determination key of *Abelmoschus* to acommodate the distinction between *A. esculentus* and *A. tuberculatus* as well as the distinction between *A. manihot, A. tetraphyllus* and *A. callei*. The existing botanical descriptors (*A. tuberculatus, A.manihot* and *A.tetraphyllus)* need to be compared with the variation in the accessions of the global base collection and other existing collections. The intraspecific classification in *A. moschatus, A. tetraphyllus, A. esculentus* and *A. angulosus* should, however, receive further attention (IBPGR, 1991).

2.2 Cytogenetic Relationship among Taxa

There are significant variations in the chromosome numbers and ploidy levels of different sepceis in the genus *Abelmoschus.* The lowest number reported is 2n=56 for *A. angulosus* (Ford, 1938), whereas the highest chromosome number reported are close to 200 for *A. manihot var. caillei* (Singh and Bhatnagar, 1975; Siemonsma, 1982a, 1982b). The chromosome number and ploidy levels of different species are given in Table 3.

Table 3: Chromosome Numbers (2n) in *Abelmoschus*

Species	Chromosome Numbers (2n)	Authors	Ploidy Level*	Genepool (GP)
A. esculentus	± 66	Ford (1938)		GP1
	72	Teshima (1933), Ugale *et al.* (1976) and Kamalova (1977)		
	108	Datta and Naug (1968)	2	
	118	Krenke In: Tischler (1931)	2	
	120	Krenke In: Tischler (1931), Purewal and Randhawa (1947) and Datta and Naug (1968)	2	
	122	Krenke In: Tischler (1931)	2	

Species	Chromosome Numbers (2n)	Authors	Ploidy Level*	Genepool (GP)
	124	Kuwada (1957, 1966)	2	
	126-134	Chizaki (1934)	2	
	130	Skovsted (1935) and Joshi and Hardas (1953); Gadwal In: Joshi and Hardas(1976); Gadwal *et al.* (1968), Joshi *et al.* (1974); and Singh and Bhatnagar (1975)		
	131-143	Siemonsma (1982a, 1982b)	2	
	132	Medwedewa (1936) and Roy and Jha (1958)	2	
	± 132	Breslavetz *et al.* (1934) and Ford (1938)	2	
	144	Datta and Naug (1968)	2	
A. manihot -ssp. manihot	60	Teshima (1933) and Chizaki (1934)	1	GP3
	66	Skovsted (1935) and Kamalova (1977)	1	
	68	Kuwada (1957, 1974)	1	
-ssp. tetraphyllus	130	Ugale *et al.* (1976)	2	GP3
var. tetraphyllus	138	Gadwal In: Joshi and Hardas (1976)	2	GP3
-ssp. tetraphyllus	138	Gadwal In: Joshi and Hardas (1976)	2	GP3
A. moschatus	72	Skovsted (1935), Gadwal *et at.* (1968); Joshi *et al.* (1974)	1	GP3
A. ficulneus	72	Hardas and Joshi (1954), Kuwada (1966, 1974), Gadwal *et al.* (1968) and Joshi *et al.* (1974)	1	GP2
	78	Skovsted (1935)	1	
A. angulosus	56	Ford (1938)	1	GP3
A. tuberculatus	58	Joshi and Hardas (1953), Kuwada (1966, 1974), Gadwal *et al.* (1968) and Joshi *et al.* (1974)	1	GP2
A. caillei	194	Singh and Bhatnagar (1975)	3	GP3
(A. manihot var. caillei)	185-199	Siemonsma (1982a, 1982b)	3	

** Ploidy level1: 2n=56-72; Ploidy level 2: 2n= 108-144; Ploidy level 3: 2n=185-199*

Source: *From Charrier, A., Genetic resources of the genus Abelmoschus Med. (Okra), IBPGR, Rome, 1984; Siemonsma, J.S. International Crop Network Series. Report of an international workshop on okra genetic resources, IBPGR, Rome, 5: 52-68 1991.*

As may be seen from the above table, the chromosome number (2n) of *A. esculentus* L. (Moench*)* have been variably reported by different authors. The most frequently observed somatic chromosome number, however, is 2n=130, although Dutta and Naug (1968) suggest that the numbers 2n=72, 108, 120, 132 and 144 are in regular series of polyploids with n=12. The existing taxonomical classifications at the speices level in the genus *Abelmoschus* are unsatisfactory. Detailed cytogenetical observations on Asian material of okra and related species are likely to provide more examples of the existence of amphidiploids in the genus (Siemonsma, 1982a).

In this context Aladele *et al.,* 2008 collected 93 accessions of okra comprising of 50 West African genotypes (*A. caillei*) and 43 Asian genotypes (*A. esculentus*) and assessed for genetic distinctiveness and

relationship using random amplified polymorhphic DNA (RAPD). The molecular analysis showed that all the thirteen primers used, revealed clear distinction between the two genotypes. There was more diversity among the Asian genotypes; this might be due to the fact that they were originally collected from six different countries in the region. Six duplicate accessions were discovered while accession TOT7444 distinguished itself from the other two okra species, an indication which suggests that it might belong to a different species. This recent study at molecular level emphasizes the need of a deeper study into the variable polymorphism at chromosomal level in the genus *Abelmoschus*.

2.3 Geographical Origin and Distribution

A. esculentus is found all around the world from Mediterranean to equatorial areas as may be seen from the geographical distribution of cultivated and wild species shown in Figure 1.

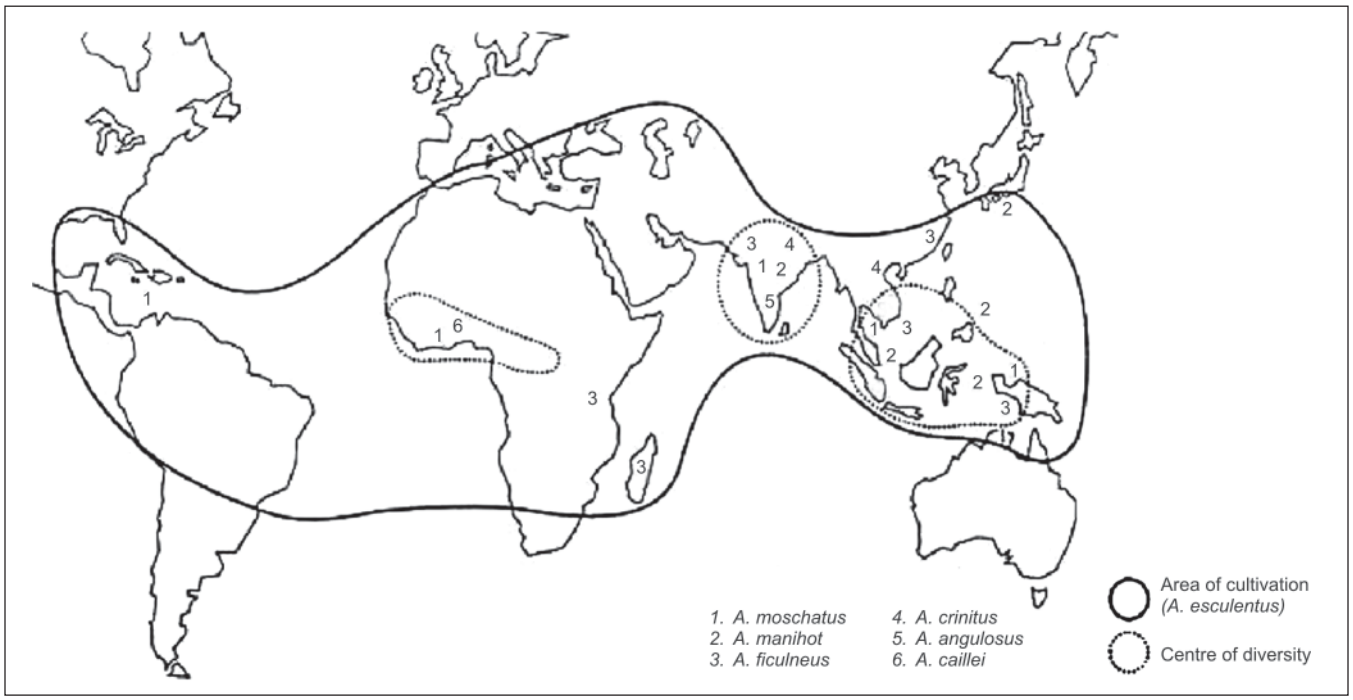

Figure 1: *Geographical distribution of Abelmoschus species modified from Charrier (1984)*

Cultivated and wild species clearly show overlapping in Southeast Asia, which is considered as the centre of diversity. The spread of the other species is the result of their introduction to America and Africa. There are two hypotheses concerning the geographical origin of *A. esculentus*. Some authors argue that one putative ancestor (*A. tuberculatus*) is native to Uttar Pradesh in northern India, suggesting that the species originated from this geographic area. Others, on the basis of ancient cultivation in East Africa and the presence of the other putative ancestor (*A. ficulneus*), suggest that the area of domestication is north Egypt or Ethiopia, but no definitive proof is available today. For *A. caillei*, only found in West Africa, it is difficult to suggest an origin outside. Its origin by hybridization with *A. manihot* is difficult to accept even if its presence, mentioned in the Flora of West Africa (Hutchinson and Dalziel, 1958) was not recently confirmed in this area and herbarium samples are lacking.

Eight *Abelmoschus* species occur in India. Out of these, *A. esculentus* is the only known cultivated species. *A. moschatus* occurs as wild species and is also cultivated for its aromatic seeds, while the rest six are truly wild types. The wild species occupy diverse habitats. The species *A. ficulneus* and *A. tuberculatus* is spread over the semi-arid areas in north and northwestern India; *A. crinitus* and *A. manihot* (*tetraphyllus* and *pungens* types) in tarai range and lower Himalayas; *A. manihot* (*tetraphyllus* types), *A. angulosus*, and *A. moschatus* in Western and Eastern Ghats; and *A. crinitus* and *A. manihot* (mostly *pungens* types) in the northeastern region, depicting their broad range of distribution in different phytogeographical regions of the country. Intra as well as interspecific variations do exist in different phyto-geographic areas. Existence of different *Abelmoschus* species in different areas of India observed in a recent survey is presented in Table 4.

Table 4: Distribution of Wild Abelmoschus Species in different Phytogeographical Regions of India

S.No.	Species	Distribution
1.	*A. angulosus*	Tamil Nadu, Kerala
2.	*A. cancellatus*	Uttaranchal, Himachal Pradesh, Uttar Pradesh, Orissa
3.	*A. criniturs*	Uttaranchal, Madhya Pradesh, Orissa
4.	*A ficulneus*	Jammu & Kashmir, Rajasthan, Madhya Pradesh, Chhattisgarh, Maharashtra, Tamil Nadu, Andhra Pradesh, Uttar Pradesh
5.	*A. manihot ssp. tetraphyllus* var. *tetraphyllus*	Uttar Pradesh, Rajasthan, Madhya Pradesh, Maharashtra, Orissa, Chhattisgarh
6.	*A. manihot ssp. tetraphyllus* var. *pungens*	Uttaranchal, Himachal Pradesh, Jammu & Kashmir, Assam, Andaman & Nicrobar Islands
7.	*A. moschatus ssp. moschatus*	Uttaranchal, Orissa, Kerala, Karnataka, Andaman & Nicobar Islands
8.	*A. moschatus ssp. tuberosus*	Kerala and parts of Western Ghats in Tamil Nadu
9.	*A. tuberculatus*	Uttar Pradesh, Rajasthan, Madhya Pradesh, Maharashtra

Source: Bisht and Bhat, 2006

3. REPRODUCTIVE BIOLOGY

3.1 Growth and Development

Okra is mainly propagated by seeds and has duration of 90-100 days. It is generally an annual plant. Its stem is robust, erect, variable in branching and varying from 0.5 to 4.0 metres in height. Leaves are alternate and usually palmately five lobed, whereas the flower is axillary and solitary. The botanical features of various plant parts are detailed in Annexure –I.

Okra plants are characterized by indeterminate growth. Flowering is continuous but highly dependent upon biotic and abiotic stress. The plant usually bears its first flower one to two months after sowing. The fruit is a capsule and grows quickly after flowering. The greatest increase in fruit length, height and diameter occurs during 4th to 6th day after pollination. It is at this stage that fruit is most often plucked

for consumption. The okra pods are harvested when immature and high in mucilage, but before becoming highly fibrous. Generally the fibre production in the fruit starts from 6th day onwards of fruit formation and a sudden increase in fibre content from 9th day is observed (Nath, 1976). Okra plants continue to flower and to fruit for an indefinite time, depending upon the variety, the season and soil moisture and fertility. Infact the regular harvesting stimulates continued fruiting, so much that it may be necessary to harvest every day in climates where growth is especially vigorous.

3.2 Floral Biology

The okra flowers are 4-8 cm in diameter, with five white to yellow petals, often with a red or purple spot at the base of each petal and the flower withers within one day. The flower structure combines hermaphroditism and self compatibility. Flower bud appears in the axil of each leaf, above 6th to 8th leaf depending upon the cultivar. The crown of the stem at this time bears 3-4 underdeveloped flowers but later on during the period of profuse flowering of the plant there may be as many as 10 undeveloped flowers on a single crown. As the stem elongates, the lower most flower buds open into flowers. There may be a period of 2, 3 or more days between the time of development of each flower but never does more than one flower appear on a single stem. A flower bud takes about 22-26 days from initiation to full bloom. The style is surrounded by a staminal column which may bear more than 100 anthers. The pollen may come in contact with the stigmas through a lengthening of the staminal column or through insect foraging (Thakur and Arora, 1986). Thus the flowers of okra are self fertile. The pollen grain is large with many pores, and every pore is a potential tube source; therefore, many tubes can develop from one pollen grain (Purewal and Randhawa, 1947).

3.3 Pollination and Fertilization

Flower bud initiation, flowering, anthesis and stigma receptivity are influenced by genotype and climatic factors like temperature and humidity (Venkatramini, 1952). From studies made on six okra varieties, Sulikeri and Swamy Rao, 1972 concluded that flower buds are initiated at 22-26 days and the first flower opened 41-48 days after sowing. Once initiated, flowering continues for 40-60 days. Anthesis was observed between 6 a.m and 10 a.m. Anthers dehisce before flower opening and hence self pollination may occur at anthesis. The dehiscence of anthers is transverse and complete dehiscence occurs in 5-10 minutes (Purewal and Randhawa, 1947). Pollen fertility is maximum in the period between an hour before and an hour after opening of the flower (Srivastava, 1964). Pollen stored for 24 hours at room temperature (27° C) and 88% relative humidity was not viable. The stigma was most receptive on the day of flowering (90-100%). Stigma receptivity was also observed the day before flowering (50-70%) and the day after (1-15%). Flowers open only once in the morning and close after pollination on the same day. The following morning the corolla withers.

Okra has perfect flowers (male and female reproductive parts in the same flower) and is self-pollinating. If okra flowers are bagged to exclude pollinators, 100% of the flowers will set seed. It has been found experimentally that there is no significant difference in fruit set under open-pollinated, self-pollinated (by bagging alone) and self-pollinated (hand pollination of bagged flowers), indicating that it is potentially

a self-pollinated crop (Purewal and Randhawa, 1947). The inbreeding depression well pronounced in cross-pollinated crops has not been reported in this crop (Duranti, 1964).

Although insects are unnecessary for pollination and fertilization in case of okra, the flowers are very attractive to bees and the plants are cross-pollinated. The cross pollination upto the extent of 4-19% (Purewal and Randhawa, 1947; Choudhury *et al.,* 1970; Shalaby, 1972) with maximum of 42.2% (Mitidieri and Vencovsky, 1974) has been reported. The extent of cross-pollination in a particular place will depend upon the cultivar, competitive flora, insect population and season, etc.

3.4 Seed Dispersal

Okra belongs to category of explosive spreaders i.e.plants in which the fruits explode at maturity and shoot the seeds several feet away from the mother plant. The seeds of okra may spread upto 2-3 metres upon shattering.

3.5 Methods of Reproductive Isolation

Okra is an example of a self-pollinating crop that requires a considerable degree of separation between varieties to maintain purity. The observation that a plant is capable of self-pollination has sometimes been made into an argument that isolation of self-pollinators is not necessary. On the contrary, the ability to self-pollinate often has little to do with the amount of cross-pollination that can occur naturally (McCormack, 2004). As mentioned above, the studies available on amount of natural cross-pollination in okra have shown that there is a considerable amount of cross-pollination. An isolation distance of 400 meters is required for production of foundation seeds of varieties/hybrids in case of okra as per Indian minimum seed certification standards (Tunwar and Singh, 1988). Accordingly requirements of 400 meters as the isolation distance for conducting confined field trial of genetically engineered okra varieties/ hybrids has been adopted in India.

4. CROSSABILITY BETWEEN *ABELMOSCHUS SPP.* AND HYBRIDIZATION

4.1 Interspecific Hybridization

Interspecific crosses have been attempted between ploidy level 1 species, between ploidy level 1 and ploidy level 2 species, between ploidy level 2 species and with ploidy level 3 species (Bisht and Bhat, 2006). Reports on interspecific crosses between *A. esculentus* (ploidy level 2) and ploidy level 1 species indicate positive results with four species as shown in Table 5. However, it may be noted that the seeds so obtained after crossing did not either germinate or produce fertile plants. The sterility is attributable to various reasons such as chromosomal differences (in case of *A. tuberculatus* and *A. ficulneus*) and genomic differences leading to irregular gamete formation (in case of *A. manihot*).

Table 5: Results of Crosses Between *Abelmoschus esculentus* and Ploidy Level 1 Species (Positive = Viable Seed)

Cross A. *esculentus* X Meiosis	Chromosome Numbers	Authors	Indicated Cross	Reciprocal Cross	Bivalents in Meiosis
A. tuberculatus		Pal *et al.* (1952)	Positive	Positive	
	130×58	Joshi and Hardas(1956) and Joshi *et al.* (1974)	Positive	Positive	28.8 (2.29)
	124×58	Kuwada (1966)	Positive	Positive	27-29
A. manihot	72×60	Teshima (1933)	Positive	Negative	0
	(126-134)×60	Chizaki (1934)	Positive		0-7
	130×66)	Skovsted (1935)	Positive	Positive	
		Ustinova (1937)	Positive	Negative	
		Singh *et al.* (1938)[a]	Positive		
		Ustinova (1949)	Positive	Negative	
		Pal *et al.* (1952)	Positive	Negative	
	124×68	Kuwada (1957)	Positive	Positive	
		Hamon and Yapo (1986)	Negative	Negative	
A. ficulneus		Pal *et al.* (1952)	Negative	Negative	
	130×72	Gadwal *et al.* (1968) & Joshi *et al.* (1974)	Negative		27.5 (26-28)[b]
A. moschatus	130×72	Skovasted (1935)	Positive	Negative	
	130×72	Gadwal *et al.* (1968)	Negative		8.3 (3-16)[b]
		Joshi *et al.* (1974) Hamon and Yapo (1986)	Positive	Negative	

a The article deals with a cross between A. esculentus and A. ficulneus, but the description of the latter species corresponds to A. manihot.
b Hybrids obtained by embryo- and/or ovule-culture.
Source: *From Charrier, A., Genetic resources of the genus Abelmoschus Med. (Okra), IBPGR, Rome, 1984; Siemonsma, J.S. International Crop Network Series. Report of an international workshop on okra genetic resources, IBPGR, Rome, 5: 52-68 1991.*

Regarding interspecific crossing between ploidy level 2 species, viable seeds but sterile hybrids have been reported in the crosses between *A. esculentus* and *A. tetraphyllus* (Joshi and Hardas, 1976; Hamon and Yapo, 1986). No data on genome affinity were presented. Artificial and spontaneous amphidiploids between these two species have been realized in India in attempts to transfer yellow vein mosaic virus (YVMV) to cultivated okra (Jambhale and Nerkar, 1981a, 1981b).

Regarding interspecific crossing between ploidy level 3 species, crosses between *A. esculentus* and *A. caillei* produced viable hybrids with strongly reduced fertility (Singh and Bhatnagar, 1975; Joshi and Hardas, 1976; Siemonsma, 1982a, 1982b; Hamon and Yapo, 1986; Hamon, 1988). Hamon and Yapo (1986) reported viable and sterile hybrids in the cross *A. caillei* X *A. tetraphyllus.*

5. ECOLOGIOCAL INTERACTIONS

5.1 Organisation of Species Complexes and Gene Flow

Affinities between cultivated okra and related wild taxa have been determined on the basis of cytogentic studies. Some degree of homology has been observed between *A. esculentus*, *A. tuberculatus* and *A. ficulneus*. It has been reported that 29 of the 65 chromosomes of *A. esculentus* had complete homology with 29 chromosomes of *A. tuberculatus* and the remaining 36 chromosomes showed greater (but still incomplete) homology with 36 chromosomes of *A. ficulneus.* Another group of polyploid species showing genetic affinity includes *A. esculentus, A. tetraphyllus and A. pungenus* (Bisht and Bhat, 2006).

5.2 Potential for Gene Transfer from Okra

5.2.1 Gene transfer between different okra species

Based on the available information on crossability, hybrids have been produced in the crosses between *A. esculentus* and *A. caillei*. It is easy to obtain F_1 plantlets irrespective of direction of crossing. It may be noted that though F_1 plants were obtained in certain cases, these plants were highly sterile and it was difficult to produce subsequent generations or even to carry out backcrosses (Singh and Bhatnagar, 1975; Joshi and Hardas, 1976; Siemonsma, 1982a, 1982b; Hamon and Yapo, 1986; Hamon, 1988).

It is more difficult to cross *A. esculentus* with wild species of the genus *Abelmoschus*. It is sometimes possible to obtain first-generation hybrids such as in crosses between *A. esculentus* and *A. tetraphyllus*, but the process is blocked at the second generation (Hamon, 1988). It is almost impossible to obtain crosses with *A. moschatus* (Hamon and Yapo, 1985). Other species, because they are rarely found in collection surveys, have hardly been tested.

5.2.2 Gene transfer from okra to other plants

There are no reports of any gene transfer from okra to unrelated plant species. Further it may be noted that such transfer of any gene is highly improbable because of pre-and post-zygotic genetic incompatibility barriers that are well documented for distantly related plant groups. No evidence for transfer of genes from okra to other plant taxa has been identified.

5.2.3 Gene transfer from okra to other organisms

Horizontal gene transfer from plants to animals (including humans) or microorganisms is extremely unlikely. No evidence has been identified for any mechanism by which okra genes could be transferred to humans or animals, nor any evidence that such gene transfer has occurred for any plant species during evolutionary history, despite animals and humans eating large quantities of plant DNA. The likelihood of okra genes transferring to humans and other animals is therefore effectively zero. Similarly gene transfer from okra, or any other plant, to microorganisms is extremely unlikely. Horizontal gene transfer from plants to bacteria has not been demonstrated experimentally under natural conditions (Nielsen *et al.*, 1997; Nielsen *et al.*, 1998; Syvanen, 1999) and deliberate attempts to induce such transfers have so far failed (Schlüter *et al,.* 1995; Coghlan, 2000).

5.3 Seed Dormancy

A. esculentus shows a particular kind of seed dormancy, called delayed permeability caused due to structure of the seed coat and particularly by the chalazal plug. There is observed a direct relationship between the seed moisture content and delayed permeability with variances between cultivars and moisture contents. Normal seeds harvested from the plants of the cultivars does not exhibit seed dormancy.

5.4 Free Living Populations of Okra

The term "free living" is assigned to plant populations that are able to survive, without direct human assistance, over long term in competition with the native flora. This is a general ecological category that includes plants that colonize open, disturbed prime habitat that is either under human control (weedy populations) or natural disturbed areas such as river banks and sand bars(wild populations). There are no such free living populations of *A. esculentus* in India.

5.5 Weediness of Okra

No reports of *A. esculentus* as a weed are available in India.

6. HUMAN HEALTH CONSIDERATIONS

In okra, no endogenous toxins or significant levels of antinutritional factors have been found till date. It is not considered a pathogen and thus not capable of causing any disease in humans, animals or plants.

7. OKRA CULTIVATION IN INDIA

7.1 Climate and Soil Requirements

Okra requires a long, warm and humid growing period. It can be successfully grown in hot humid areas. It is sensitive to frost and extremely low temperatures. For normal growth and development a temperature between 24°C and 28°C is preferred. At 24°C the first flower bud may appear in the third leaf axil while at 28°C it may appear in sixth leaf axil. This higher position is not necessarily accompanied with a delay in time because at higher temperatures the plants grow faster and the higher position is reached earlier. For faster plant growth still higher temperature helps though it delays the fruiting. But at higher temperatures beyond 40°–42°C, flowers may desiccate and drop, causing yield losses.

For seed germination, optimum soil moisture and a temperature between 25°C and 35°C is needed with fastest germination observed at 35°C. Beyond this range the germination will be delayed and weak seeds may not even germinate.

Adjustment of climatic factors helps in taking at least one (summer) crop in hills, two or even three (summer, kharif and late kharif) crops in the east, west and north Indian plains and almost year-round cultivation under moderate climate in south India. It is grown on sandy to clay soils but due to its well-developed tap root system, relatively light, well-drained, rich soils are ideal. As such, loose, friable, well manured loam soils are desirable. A pH of 6.0–6.8 is ideally-suited. However, the cultivar Pusa Sawani has some tolerance to salts and thus also to a larger pH range. All soils need to be pulverized, moistened and enriched with organic matter before sowing.

7.2 Varietal Testing System

As okra is grown all over India and round the year, like other similar vegetable crops, okra is tested in the All India Coordinated Vegetable Improvement Programme (AICVIP), spread at the selected locations in the country. State Universities and Research Stations of the Indian Council of Agricutural Research (ICAR) evaluate the improved genotypes and identify sutabile cultivars for cultivation in the area under their jurisdiction. The AICVIP promotes R&D and breeding of improved varieties of vegetable crops including okra. Vegetable growing states in India are classified into eight different zones, mainly on the basis of agro-climatic conditions and these are listed below:

Zone I: Jammu & Kashmir, Himachal Pradesh and Uttarakhand
Zone II: West Bengal and Assam
Zone III: North East States and Andaman and Nicobar Islands
Zone IV: Punjab, Uttar Pradesh, Bihar and Jharkhand
Zone V: Chhattisgarh, Orissa and Andhra Pradesh
Zone VI: Rajasthan, Gujarat, Haryana and Delhi
Zone VII: Madhya Pradesh and Maharashtra
Zone VIII: Karnataka, Tamil Nadu and Kerala

7.3 Pests and Diseases of Okra

Insect pest infestation is one of the most limiting factors for accelerating yield potential of okra. The crop is prone to damage by various insects, fungi, nematodes and viruses, although there is wide variability in their degree of infestation. Some of the important insects are fruit and shoot borer, aphids, jassids white flies, ants, etc. Okra is also prone to the attack of many diseases causing pathogens affecting leaves, flowers and fruits. The most serious disease of okra is yellow vein mosaic virus (YVMV) in India caused by YVM virus. The major insect pests and diseases of okra in India are detailed in Annexure II and III.

7.4 Breeding Objectives

Genetic improvement in the following traits has been identified for increased productivity in terms of time and area of cultivation. Breeder's objectives are as follows:

i. To breed early maturing and late senescing varieties.
ii. To evolve high yielding varieties and hybrids capable of an increased marketable yield of dark green, tender, long, smooth pods. High yield of seed would be an added advantage.
iii. To develop varieties resistant to virus diseases such as YVM and leafcurl; fungal diseases such as vascular wilt, *Cercospora* blight, powdery mildew, fruit rot and damping off; insect pests such as shoot and fruit borer, leafhopper, apdhids, whitefly etc.
iv. To breed varieties with optimum seed setting ability for rapid multiplication.
v. To develop varieties suitable for export market. e.g. short, smooth fruit.
vi. To evolve varieties and hybrids for wider adaptability.
vii. To develop multiple disease–resistant and pest resistant varieties, with special emphasis on combining

yellow vein mosaic virus resistance with resistance to fruit and shoot borer.

7.5 Germplasm Conservation

More than 2,500 accessions of cultivated and wild species are maintained both as base collection in the National Genebank at National Bureau of Plant Genetic Resouces, NBPGR, (long-term storage at -20°C) and as active collection under medium term storage (4°C) at NBPGR Regional Station in Akola, Maharashtra. In addition, working collections are maintained at Indian Institute of Horticultural Research (IIHR), Bangalore; Marathwada Agricultural University (MAU), Parbhani; Orissa University of Agriculture & Technology (OUAT), Bhubaneswar; Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar; Punjab Agricultural University (PAU), Ludhiana; Chandra Sekhar Azad University of Agriculture & Technology (CSAUAT), Kanpur; Tamil Nadu Agricultural University (TNAU), Coimbatore; Anand Agricultural University (AAU), Anand, Gujarat; and Indian Agricultural Research Institute (IARI), New Delhi.

As per recent International Plant Genetic Resources Institute (IPGRI) germplasm database, more than 46 institutions in different countries worldwide possess about 11,000 accessions of cultivated okra and wild related species. Major institutions are holding more than 100 accessions.

7.6 Status of Okra Cultivation

In India the major okra producing states are West Bengal, Bihar, Orissa, Andhra Pradesh, Gujarat, Jharkhand, Chhattisgarh and Maharashtra. The area and production data in major okra growing states in 2008-2009 are illustrated in Figure 2.

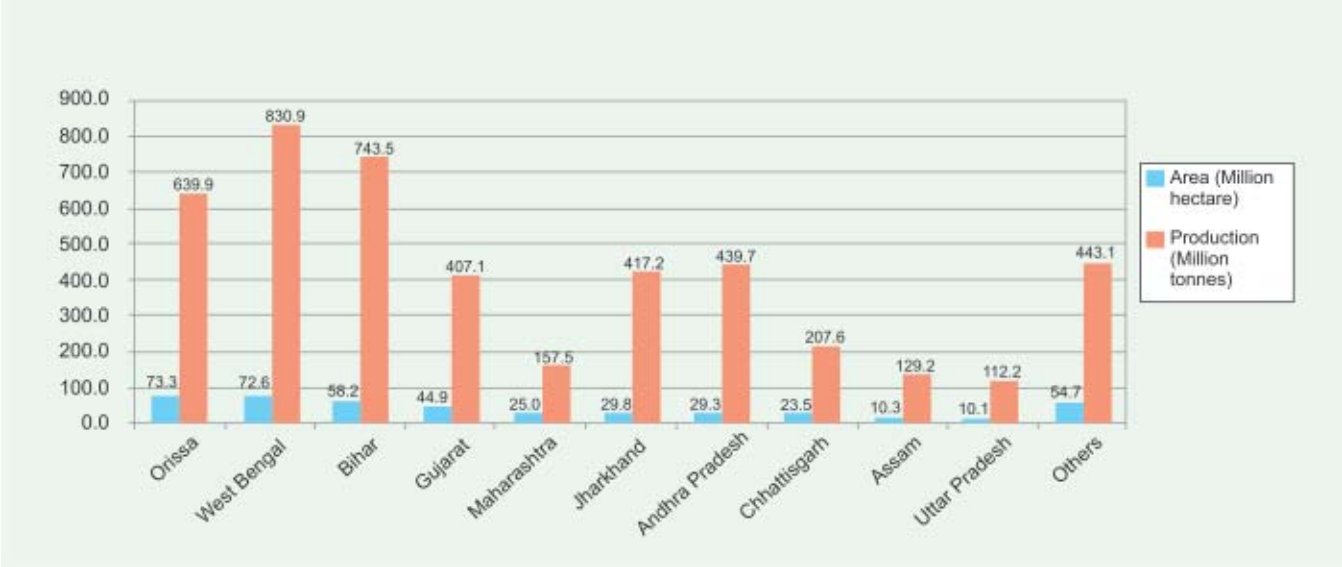

Figure 2: *Statewise area and production of okra for the year 2008-2009*
Source: *www.nhb.gov.in*

A. manihot sp. *tertaphyllus* var. *megaspermus hemadri* is reported only from Indian states of Maharashtra, Gujarat and Madhya Pradesh cultivated in shady hill slopes and foot hills. *A. tuberculatus* is endemic to India and is the close relative of cultivated okra, *A. esculentus.* It is widely distributed in semi-arid regions of north and northwestern parts of India including Uttar Pradesh, Rajasthan, Madhya Pradesh, Maharashtra, Gujarat, and parts of Andhra Pradesh (Pal *et al.*, 1952).

7.7 Status of Biotechnological Interventions

Shoot and fruit borer i.e. *Earias sp.* being the most destructive pest in okra crop, efforts have been made to develop insect resistant okra varieties by incorporating *cry1Ac* gene from *Bacillus thuringiensis*, commonly known as Bt okra. The Bt okra developed by M/s Maharashtra Hybrid Seeds Company Limited containing *cry1Ac* gene (Event OE-17A) is under safety evaluation and confined field trials.

Among viral diseases, Yellow Vein Mosaic virus being major disease of okra, attempts are being made by M/s Arya Hybrid Seeds Ltd., for incorporation of specific genes such as CP (coat protein) gene and antisense RNA gene for elevated viral resistance.

ANNEXURE - I

BOTANICAL FEATURES OF OKRA

Okra is an upright annual, herbaceous 3 to 8 feet tall plant with a hibiscus-like flower. It is a tropical direct sown vegetable with a duration of 90-100 days. The botanical features are as indicated below:

Root

Okra plant has a deep taproot system.

Stem

Its stem is semi woody and sometimes pigmented with a green or reddish tinges color. It is erect, variable in branching, with many short branches that are attached to thick semi woody stem. The stem attains height from 3 feet in dwarf varieties to 7 or 8 feet in others.

Leaves

The woody stem bear leaves that are lobed and are generally hairy, some reaching up to 12 inches in length. Leaves are cordate (heart-shaped), simple, usually palmately 3-7 lobed and veined. Leaves are subtended by a pair of narrow stipules. The okra leaf is dark green in color and resembles a maple leaf.

Flowers

The flowers are borne vertically only on the orthotropic axis every two or three days. The flower is axillary and solitary, borne on a peduncle 2.0 – 2.5 cm long. The flowers are large around 2 inches in diameter, with five white to yellow petals with a red or purple spot at the base of each petal. Flower lasts only for a day. Each blossom develops a small green pod. The flowers are almost always bisexual and actinomorphic. The perianth consists of 5 valvate, distinct or basally connate sepals and 5 distinct petals that are usually basally adnate to the androecium (Figure 3).

Figure 3: *Okra flower bud and immature seed pod*

The androecium consists numerous monadelphous stamens with apically divergent filaments bearing 1-celled anthers. The gynoecium is a single compound pistil of two to many carpels, an equal number of styles or style branches, and a superior ovary with two to many locules, each bearing one to numerous ovules. The calyx is completely fused to form a protective case for the floral bud and spilts into lobes when the bud opens. The calyx, corolla and stamens are fused together at the base and fall off as one piece after anthesis (Figure 4).

The erect sexual parts consist of a five to nine part style, each part with a capitate stigma, surrounded by the staminal tube bearing numerous filaments (Purewal and Randhawa 1947, Purseglove 1968). The petals wilt in the afternoon and usually fall the following day.

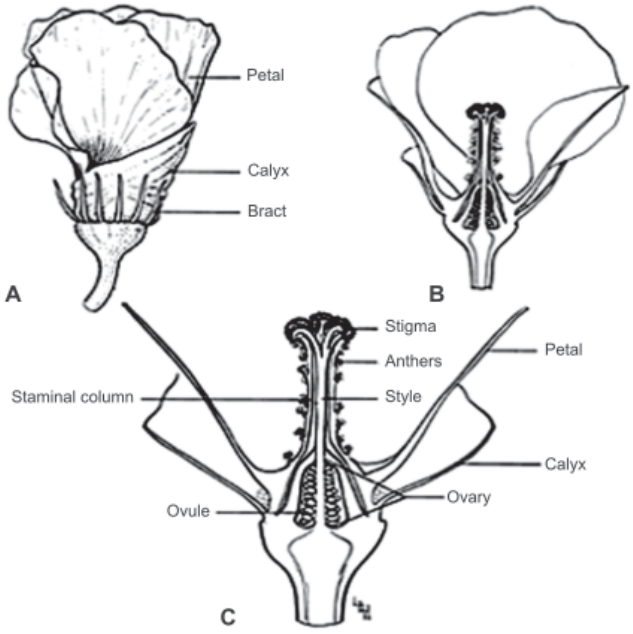

Figure 4: *Okra flower. A Side view; B longitudinal section; C longitudinal section of staminal column*

Fruit

The fruit is an elongated, conical or cylindrical capsule, comprising for the most part, five cavities containg ovules (Figure 5). The fruit is actually long pod and generally ribbed, developing in the leaf axil and spinelesss in cultivated kinds. The fruit is normally yellowish green to green, but is sometimes purple or whitish green. The pods are the edible portion, which are harvested while still tender and immature. They grow rapidly into long (10-30 cm) and narrow (1-4 cm) pod with a tip that is either pointed like a beak or blunt.

Figure 5: *Okra Fruit*
Source: *http://www.wiu.edu/*

Seeds

The okra fruit contains numerous oval, smooth, striated and dark green to dark brown seeds (Figure 6).

Figure 6: *Okra Seeds*
Source: *http://www.wiu.edu/*

ANNEXURE - II

KEY INSECT PESTS OF OKRA

The major insect pests of okra include shoot and fruit borer (*Earias sp*), Fruit Borer (*Helicoverpa armigera*) and some other sucking pests such as jassids, aphids, ants and whitefly.

i) Shoot and Fruit Borer (*Earias sp.*)

The fore wings of *E. vittella* are pale white and with broad wedge shaped horizontal green band in the middle, while in *E. insulana* are uniformly green (Figure 7). Full grown larvae are stout, brownish with milky white markings (Figure 8).

Figure 7: *Adult of Shoot and Fruit Borer (Earias sp.)*

Figure 8: *Larvae of Shoot and Fruit Borer (Earias sp.)*

Figure 9: *Fruit damage by Shoot and Fruit Borer (Earias sp.)*

Source: *Maharashtra Hybrid Seeds Company Ltd*

Larvae bore into the tender shoots tunneling downwards and the affected shoots wither and growing points are killed. The entrance hole is plugged with excreta. The caterpillars bore inside the developing buds, flowers, fruits and feed on inner tissues (Figure 9). Damaged buds and flowers fall while affected fruits are distorted.

ii) Fruit Borer (Helicoverpa armigera)

Moths are medium sized, pale brown, olive green to brown wings with dark brown circular spots in the center (Figure 10). Each moth lays hundreds of eggs. The young larvae feed on tender foliage, while advanced stages attack the fruits, bore circular holes inside the fruit (Figure 11). Larvae move from one fruit to another and may destroy many fruits. External symptoms appear in the form of a bored hole.

Figure 10: *Adult of Fruit Borer (Helicoverpa armigera)*
Source: *http://ppis.moag.gov.*

Figure 11: *Larvae of Fruit Borer (Helicoverpa armigera)*
Source: *http://sindominio.net/*

iii) Sucking Pests

1. Jassids (*Amrasca biguttula biguttula*)

The adults are wedge shaped (2 mm) pale green with a black spot on posterior half of each of the fore wings (Figure 12). The female inserts about 15 yellow eggs into leaf veins on the underside. Nymphs and adults suck sap usually from the under surface of the leaves and inject toxins causing curling of leaf edges and leaves turn red or brown called as 'Hopper Burn'. The leaves dry up and shed. On transformation into winged adults, they feed constantly on the plant juice.

Figure 12: Jassids (*Amrasca biguttula biguttula)*
Source: *http://sindominio.net/*

2. Whiteflies (*Bemisia tabaci*)

The insect breeds throughout the year and the female lays stalked yellow spindle shaped eggs singly on the lower surface of the leaf (Figure 13). Nymphs and adults suck the sap usually from the under surface of the leaves and excrete honeydew. Leaves appear sickly and get coated with sooty mold. The whitefly serves as the vector for the spread of yellow vein mosaic virus (YVMV) disease causing damage to okra crop.

Figure 13: Whitefiles *(Bemisia tabaci)*
Source: *http://c.photoshelter.com*

3. Green Peach Aphid (*Myzus persicae*)

Soft-bodied, pear-shaped insects with a pair of dark cornicles and a cauda protruding from the abdomen; yellow-green nymph, may be winged or wingless - wingless forms most common (Figure 14, 15). These are known to feed in colonies.

Green peach aphids can attain very high densities on young plant tissue, causing water stress, wilting, and reduced growth rate of the plant.

Figure 14: *Adult of Green Peach Aphid (Myzus persicae)*
Source: *http://matrixbookstore.biz*

Figure 15: *Nymphs of Green Peach Aphid (Myzus persicae)*
Soucre: *http://entnemdept.ufl.edu*

4. Ants

Ants can be very destructive to okra pods (Figure 16). Ants feed on the moisture and sugar content of okra. These cause discoloration or distortion of plant.

Figure 16: *Ants*
Soucre: *http://issg.org*

iv) Red Spider Mites

It is a minor and irregular non insect pest of the crop. The nymphs and adults are red in color (Figure 17). Its infestation is severe in dry and warm atmosphere. The nymphs and adult suck the cell saps from under surface of the leaf and ultimately cause defoliation. The leaf dries and is dropped away in case of severe infestation. Colonies of red mites are found feeding on ventral surface of leaves under protective cover of fine silken webs, resulting in whitish yellow spots on dorsal surface of leaves

Figure 17: *Red Spider Mites*
Soucre: *http://ikisan.com*

v) Root-knot Nematodes

Okra is highly susceptible to root-knot nematodes, *Meloidogyne* species. The above ground symptoms are similar to those described for root rot and wilt diseases. Only the difference is appearance of root galls/knots of different sizes, instead of root rotting. The infected roots also become enlarged and distorted. Root-knot nematode has wide host range. Weed management, crop rotation and intercropping or mix cropping or cover cropping with non host is recommended.

vi) European Corn Borer and Vegetable Leaf Minor

European Corn Borer and Vegetable Leaf Minor are also known to feed on the okra plant, e.g., within the stalk or leaf mesophyll and so affect the okra leaves mainly (Figure 18).

Figure 18: *Damaged Okra leaves*
Source: *newhomeeconomics.files.wordpress.com/*

ANNEXURE - III

MAJOR DISEASES OF OKRA

The okra plant has the following diseases associated with it.

i) Yellow Vein Mosaic Virus (YVMV)

Causative agent: Yellow Vein Mosaic Virus

This is the most important and destructive viral disease in okra that infects crop at all the stages growth. The characteristic symptoms of the disease are a homogenous interwoven network of yellow veins enclosing islands of green tissues (Figure 19).

Initially infected leaves exhibit only yellow coloured veins but in the later stages, the entire leaf turns completely yellow. In extreme cases, the infected leaf become totally light yellow or cream coloured and there is no trace of green colour.

Figure 19: *Okra leaves infected with Okra Yellow Vein Mosaic Virus*
Soucre: *http://ikisan.com*

At times, enations (raised structures) are observed on the under surface of infected leaf. Plants infected in the early stages remain stunted. The fruits of the infected plants become pale yellow to white in color, deformed, small and tough in texture. The disease causes 50-100% loss in yield and quality if the plants get infected within 20 days after germination.

ii) Cercospora Leaf Spot

Causative agent: *Cercospora abelmoschi, C. malayensis, C. hibisci*

In India, three species of *Cercospora* produce leaf spots in okra C. *malayensis* causes brown, irregular spots and C. *abelmoschi* causes sooty black, angular spots (Figure 20). The affected leaves roll, wilt and fall. The leaf spots cause severe defoliation and are common during humid seasons.

Figure 20: *Cercospora Leaf Spot infection in Okra*
Soucre: *http://www.ikisan.com*

The fungi survive through conidia present on the crop residue in soil. When the disease is severe, it produces complete defoliation.

iii) Fusarium Wilt

Causative agent: *Fusarium oxysporum f. sp. vasinfectum*

Fursarium wilt, a serious disease, found wherever okra is grown intensively. The fungi persist in the soil for a very long time through chlamydospore formation. Initially the plants show temporary wilting symptoms, which become permanent and progressive, affecting more plants. The leaves of the affected plants show yellowing, loose turgidity and show drooping symptoms. Eventually, the plant dies. In older plants, leaves wilt suddenly and vascular bundles in the collar region become yellow or brown. The fungus invades the roots, colonizes the vascular system and thereby restrict water translocation. Cutting the base of the stem reveals a dark woody portion along with dark brown streak underside of bark. The disease is soil borne and spread through interculture operation.

iv) Powdery Mildew

Causative agent: *Erysiphe cichoracearum, Sphaerotheca fuliginea*

Powdery mildew is caused by *Erysiphe cichoracearum* and *Sphaerotheca fuliginea.* The disease caused by the former is most common in okra growing areas where as the latter has been reported from Bangalore lately. The disease affects mainly the older leaves, petioles and stems of plants. Yields of many of the infected vegetables are reduced due to premature foliage loss. Increased humidity can increase the severity of the disease, and infection is enhanced during periods of heavy dew. The disease symptoms appear as blotches of white powdery coating are mainly on the lower surface of the leaves but may appear on the upper leaf surface also (Figure 21).

Figure 21: *Powdery Mildew (Erysiphe cichoracearum) in Okra*
Soucre: *http://ikisan.com*

Young leaves are almost immune. A large part of the leaf surface is covered by the talc-like powder composed of spores. These spores are easily blown by winds to nearby susceptible plants. Heavily infected leaves become yellow, then become dry and brown. Extensive premature defoliation of the older leaves occurs if the disease is not controlled.

v) Damping Off

Causative agent: *Pythium* spp., *Rhizoctonia* spp.

Damping off disease may kill seedlings before or soon after they emerge. Infection before seedling emergence results in poor germination due to decay of seeds in soil. If the decay of the seedlings starts at emergence they fall over the ground and die which is referred to as "damp-off". The severity of the disease depends on the amount of pathogen in the soil and on environmental conditions. When seedlings on emergence develop a lesion near the collar region, the tissue beneath the lesion soaks water and becomes soft due to which the seedlings topple down on the ground and collapse.

Cool, cloudy weather, high humidity, wet soils, compacted soil, and overcrowding especially favour development of damping-off.

vi) Enation Leaf Curl

The natural transmission of the disease agent occurs through whitefly. The important symptoms of this disease are curling of leaves in an adaxial direction, and mild or bold enations on the under surface of the leaves (become thick and deformed). The most characteristic symptom of this disease is twisting of the main stem and lateral branches Twisting of leaf petiole is conspicuous. The leaves become thick and leathery in structure. In case of heavy infection the newly emerged leaves also exhibit bold enations, thickening and curling. The infected leaves become thick and leathary. The plant growth is retarded. Fruits from infected plants are small and deformed and unfit for marketing.

vii) Root-Decaying Disease

This disease results in the death of the young seedlings. They are more prevalent when the crop is planted in cold, wet soil.

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